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ABSTRACT:

CHG DATE=20010704 STATUS=O> A device and method for separating heavier and lighter fractions of a fluid sample. The device includes a plurality of constituents comprising a container and a composite element in the container. The composite element is a separator comprising a

deformable bellows, a ballast mounted to the lower end of the bellows, and a float is engageable with an upper end of the bellows. A fluid sample is delivered to the container and the device is subjected to centrifugation whereby the centrifugal load causes the ballast to move toward the bottom of the tube and causes an elongation and narrowing of the bellows. The separator then moves down the tube and stabilizes in a position between the separated phases of the fluid sample. Termination of the centrifugal load enables the bellows to return to its original condition in sealing engagement with the walls of the tube. The dense formed phase of the fluid sample will lie between the separator and the bottom of the tube, while less dense liquid phase of the fluid sample will be the separator. <IMAGE>

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(54) Device and method for separating components of a fluid sample

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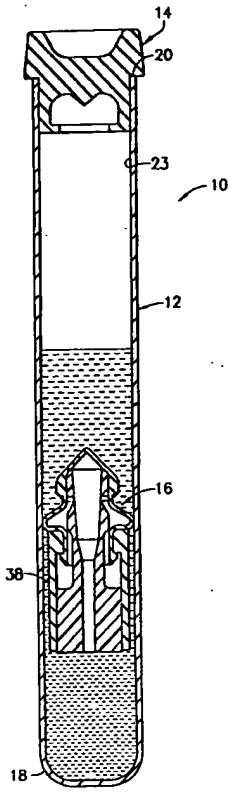

FIG.15

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] This invention relates to a device and method for separating heavier and lighter fractions of a fluid sample. More particularly, this invention relates to a device and method for collecting and transporting fluid samples whereby the device and fluid sample are subjected to centrifugation in order to cause separation of the heavier fraction from the lighter fraction of the fluid sample.

2. Description of Related Art

[0002] Diagnostic tests may require separation of a patient's whole blood sample into components, such as serum or plasma, the lighter phase component, and red blood cells, the heavier phase component. Samples of whole blood are typically collected by venipuncture through a cannula or needle attached to a syringe or an evacuated collection tube. Separation of the blood into serum or plasma and red blood cells is then accomplished by rotation of the syringe or tube in a centrifuge. Such arrangements use a barrier for moving into an area adjacent the two phases of the sample being separated to maintain the components separated for subsequent examination of the individual components.

[0003] A variety of devices have been used in collection devices to divide the area between the heavier and lighter phases of a fluid sample.

[0004] The most widely used device includes thixotropic gel materials such as polyester gels in a tube. The present polyester gel serum separation tubes require special manufacturing equipment to prepare the gel and to fill the tubes. Moreover, the shelf-life of the product is limited in that overtime globules may be released from the gel mass. These globules may be present in the serum and may clog the measuring instruments, such as the instrument probes used during the clinical examination of the sample collected in the tube. Such clogging can lead to considerable downtime for the instrument to remove the clog.

[0005] No commercially available gel is completely chemically inert to all analytes. If certain drugs are present in the blood sample when it is taken, there can be an adverse chemical reaction with the gel interface.

[0006] Therefore, a need exists for a separator device that (i) is easily used to separate a blood sample; (ii) is independent of temperature during storage and shipping; (iii) is stable to radiation sterilization; (iv) employs the benefits of a thixotropic gel barrier yet avoids the disadvantages of placing a gel in contact with the separated blood components; (v) minimizes cross contamination of the heavier and lighter phases of the sample during centrifugation; (vi) minimizes adhesion of the lower and higher density materials against the separator device; (vii) is able to move into position to form a barrier in less time than conventional methods and devices; (viii) is able to provide a clearer specimen with less cell contamination than conventional methods and devices; and (ix) can be used with standard sampling equipment.

SUMMARY OF THE INVENTION

[0007] The present invention is a method and assembly for separating a fluid sample into a higher specific gravity phase and a lower specific gravity phase. Desirably, the assembly of the present invention comprises a plurality of constituents. Preferably, the assembly comprises a container and a composite element.

[0008] Most preferably, the container is a tube and the composite element is a separator arranged to move in the tube under the action of centrifugal force in order to separate the portions of a fluid sample.

[0009] Most preferably, the tube comprises an open end, a closed end and a sidewall extending between the open end and closed end. The sidewall comprises an outer surface and an inner surface. The tube further comprises a closure disposed to fit in the open end of the tube with a resealable septum. Alternatively, both ends of the tube may be open, and both ends of the tube may be sealed by elastomeric closures. At least one of the closures of the tube may include a needle pierceable resealable septum.

[0010] Preferably, the separator element comprises an overall specific gravity at a target specific gravity of σ_t. The target specific gravity is that required to separate a fluid sample into at least two phases.

[0011] Preferably, the separator comprises at least two or more regions of differing specific gravities. Preferably, at least one of the regions is higher than the target specific gravity and at least one of the regions is lower than the target specific gravity.

[0012] The separator is disposed in the tube at a location between the top closure and the bottom of the tube. The separator includes opposed top and bottom ends and comprises a bellows, a ballast and a float. The components of the separator are dimensioned and configured to achieve an overall density for the separator that lies between the densities of the phases of a fluid sample, such as a blood sample.

[0013] The bellows of the separator is molded from a resiliently deformable material that exhibits good sealing characteristics when placed against an adjacent surface. The bellows has an upper end that is at or in proximity to the top end of the separator and an opposed lower end that is disposed between the opposed ends of the separator.

[0014] The upper end of the bellows may be formed from a needle pierceable material that may be pierced by a needle cannula for depositing a fluid sample into the tube. Additionally, the upper end of the bellows initially may be engaged releasably with the closure

mounted in th op n top nd of th tub .

[0015] Pr ferably, the bellows includes a toroidal sealing section which, in an unbiased stat of th bellows, defines an outer diameter that xce ds the inside diameter of the tub . However, th b llows can b deformed slightly so that the outer circumferential surface of the toroidal sealing section is biased against the inner circumferential surface of the tube to achieve a sealing engagement between the bellows and the tube. The bellows may be elongated by oppositely directed forces in proximity to the opposed upper and lower ends thereof. Elongation of the bellows in response to such oppositely directed forces will reduce the outside diameter of the toroidal sealing section of the bellows. Sufficient elongation of the bellows will cause the toroidal sealing section of the bellows to be spaced inwardly from the internal surface of the blood collection tube.

[0016] Desirably, the toroidal sealing section may be comprised of any natural or synthetic elastomer or mixture thereof, that is inert to the fluid sample of interest and is flexible.

[0017] Preferably, the toroidal sealing section comprises a qualitative stiffness, expressed as follows:

$$S^* = \frac{k}{a\rho_w D^2}$$

whereby S^* is the non-dimensional stiffness coefficient, k is a force required to deflect the bellows a given length, a is the applied acceleration, D is the diameter of the toroidal sealing section and ρ_w is the density of water.

[0018] Desirably, the qualitative stiffness of the toroidal sealing section is from about 0.00006 to about 190.

[0019] Preferably, the toroidal sealing section may be subjected to a characteristic or radial deflection under an applied load such as an axially applied load. The characteristic or radial deflection is defined as a change in length of the toroidal sealing section relative to the change in cross section diameter of the toroidal sealing section. Preferably, the toroidal sealing section has a characteristic or radial deflection ratio of about 1.5 to about 3.5.

[0020] Preferably, the toroidal sealing section when subjected to an applied load, such as centrifugation, to cause axial deformation of the toroidal sealing section, the change in cross section diameter of the toroidal sealing section may be expressed as follows:

$$\frac{D_{before} - D_{during}}{D_{before}} X\ 100\% = \Delta D_m$$

wherein ΔD_m is from about 5% to about 20%.

[0021] Therefore, a change in cross section diameter of the toroidal sealing section is proportional to the undeflected cross section diameter of the toroidal sealing section. Preferably, the proportion is from about .03 to about .20.

[0022] Preferably, the ballast is a substantially tubular structure formed from a mat rial having a gr ater density than the heavy phas of blood. The generally tubular ballast has a maximum outsid diameter that is less than the inside diameter of the tube. Hence, the ballast can be disposed concentrically within and spaced from a cylindrical sidewall of the tube. The ballast may be securely and permanently mounted to the lower end of the bellows.

[0023] Preferably, the float is formed from a material having a density less than the density of the lighter phase of the blood and may be engaged near the upper end of the bellows. Additionally, the float is movable relative to the ballast. For example, the float may be substantially tubular and may be slidably telescoped concentrically within the tubular ballast. Hence, the float and the ballast can move in opposite respective directions within the tube.

[0024] In use, a fluid sample enters the assembly by needle. The needle pierces a portion of the bellows adjacent the top end of the separator and partially through the hollow interior of the float. The needle is withdrawn from the assembly and the septum of the closure and the bellows reseals.

[0025] The assembly is then subjected to centrifugation. Forces exerted by the centrifuge causes a gradual separation of the phases of the fluid sample such that the more dense phase moves toward the bottom end of the tube, and the less dense liquid is displaced to regions of the tube above the more dense phase. Simultaneously, the centrifugal load will cause the dense ballast to move outwardly relative to the axis of rotation and toward the bottom of the tube. This movement of the ballast will generate an elongation and narrowing of the bellows. Thus, the outside diameter of the toroidal sealing section of the bellows will become less than the inside diameter of the tube. Additionally, the centrifugal load and the deformation of the bellows will cause the separator to disengage from the top closure. Hence, the separator will begin to move toward the bottom of the tube. Air trapped between the fluid sample and the separator initially will move through the circumferential space between the separator and the tube. After sufficient movement, the bottom end of the separator will contact the surface of the fluid sample. At this point, air trapped within the hollow interior of the separator can impede further downward movement of the separator into the fluid sample. However, this air can pass through the defect in the bellows caused by the needle or through some other manufactured defect in the bellows.

[0026] The ballast will cause the separator to sink into the fluid sample while the float will buoyantly remain near the surface of the fluid sample thereby causing an elongation and narrowing of the bellows. The separator is not abl t mov in th tube without friction between the separator and th inn r wall surface of the tub . Th less dense liquid phase of th fluid sample will move

through th spac betw en th separator and th walls of th tub . As noted abov , the overall density of the s parator is s lect d to b less than th d nsity of th formed phase of the fluid sample, but gr ater than the d nsity of the less d ns liquid phas of th fluid sample. Thus, the separator will stabilize at a location between the formed and liquid phases of the fluid sample after a sufficient period of centrifugation. The centrifuge then is stopped. The termination of the centrifugal load enables the toroidal sealing section of the bellows to return toward its unbiased dimensions, and into sealing engagement with the interior of the tube. The less dense liquid phase of the fluid sample can be separated from the tube by either removing the closure or passing a needle through the closure. Alternatively, in certain embodiments, the more dense formed phase can be accessed through a sealed opening in the bottom end of the tube.

[0027] The separator of the present invention comprises a useful range of parameters and there are two principle driving equations for defining the parameters:

$$\sigma_t V_t = \sigma_f V_f + \sigma_s V_s$$

(conservation of mass)

$$((\sigma_f - \sigma_t) V_f - (\sigma_s - \sigma_t) V_s) \rho_w = \frac{\sigma \bullet \Delta D \bullet k}{a}$$

(force balance)

[0028] The following non-dimensional parameters may then be substituted into the force balance:

$$V_s^* = V_s/D^3;\ V_f^* = V_f/D^3;\ S^* = k/a\ \rho_w D^2$$

to arrive at:

$$((\sigma_f - \sigma_t) V_f^* - (\sigma_s - \sigma_t) V_s^*) = \frac{\delta \bullet \Delta D \bullet S^*}{D}$$

So as to scale prototypes to any size device, wherein the following are defined:

σ_t, σ_f, σ_s are the specific gravities of the separator device, float and ballast, respectively;
V_t, V_f, V_s are the volumes of the separator device, float and ballast, respectively;
ρ_w is the density of water;
k is the separator spring constant;
a is the applied acceleration; and
δ is the deflection ration defined by: $\Delta L/\Delta D$, where ΔL is the change in length.

[0029] The left sid of the equation can be an infinite numb r of combinations of materials and geometries and if it is equal to the product of the right side it can be concluded that the device will function.

[0030] Desirable values for th right side of the equation are as follows:

δ=1.5-3.5
$\Delta D/D$ = .05 to .2
S^* = 0.043 to 0.220.

[0031] The assembly of the present invention is advantageous over existing separation products that use gel. In particular the assembly of the present invention will not interfere with analytes as compared to gels that may interfere with analytes. Another attribute of the present invention is that the assembly of the present invention will not interfere with therapeutic drug monitoring analytes.

[0032] Most notably, the time to separate a fluid sample into separate densities is achieved in substantially less time with the assembly of the present invention as compared to assemblies that use gel.

[0033] Another notable advantage of the present invention is that fluid specimens are not subjected to low density gel residuals that are at times available in products that use gel.

[0034] A further attribute of the present invention is that there is no interference with instrument probes.

[0035] Another attribute of the present invention is that samples for blood banking tests are more acceptable than when a gel separator is used.

[0036] Another attribute of the present invention is that only the substantially cell-free serum fraction of a blood sample is exposed to the top surface of the separator, thus providing practitioners with a clean sample.

[0037] A further attribute of the present invention is that the separator moves in the tube without friction between the separator and the inner wall of the tube under the action of centrifugal force.

[0038] Additionally, the assembly of the present invention does not require any additional steps or treatment by a medical practitioner, whereby a blood or fluid sample is drawn in the standard fashion, using standard sampling equipment.

DESCRIPTION OF THE DRAWINGS

[0039] FIG. 1 is an exploded perspective view of the assembly of the present invention.

[0040] FIG. 2 is a perspective view of the closure of the assembly of FIG. 1.

[0041] FIG. 3 is a bottom plan view of the closure of FIG. 2.

[0042] FIG. 4 is a cross-sectional view of the closure of FIG. 3 thereof.

[0043] FIG. 5 is a perspective view of the bellows of the separator of the assembly of FIG. 1.

[0044] FIG. 6 is a cross-sectional vi w of th b llows of FIG. 5 tak n along lin 6-6 thereof.

[0045] FIG. 7 is a bottom plan view of the ballast of

th separator of th assembly of FIG. 1.

[0046] FIG. 8 is a cross-sectional view of the ballast of FIG. 7 taken along line 8-8 th r of.

[0047] FIG. 9 is a perspective vi w of the float of th separator of th assembly of FIG. 1.

[0048] FIG. 10 is a side elevational view of the float of the separator of the assembly of FIG. 1.

[0049] FIG. 11 is a cross-sectional view of the float of FIG. 10 taken along line 11-11 thereof.

[0050] FIG. 12 is a side elevational view of the assembly of the present invention.

[0051] FIG. 13 is a cross-sectional view of the assembly of FIG. 12 taken along line 13-13 thereof.

[0052] FIG. 14 is a cross-sectional view of the assembly of FIG. 12 taken along line 13-13 thereof, showing the separator under a centrifugal load.

[0053] FIG. 15 is a cross-sectional view of the assembly of FIG. 12 taken along line 13-13 thereof, showing the separator sealingly engaged with the tube between the liquid and formed phases of the fluid sample.

[0054] FIG. 16 is a cross-sectional view similar to FIG. 13, but showing an alternate embodiment of the present invention.

DETAILED DESCRIPTION

[0055] The present invention may be embodied in other specific forms and is not limited to any specific embodiments described in detail, which are merely exemplary. Various other modifications will be apparent to and readily made by those skilled in the art without departing from the scope and spirit of the invention. The scope of the invention will be measured by the appended claims and their equivalents.

[0056] The present invention is illustrated in FIGS. 1 and 13-16, wherein assembly **10** includes a tube **12**, a closure **14** and a separator assembly **16**. Tube **12** includes a closed bottom **18**, an open top **20** and a cylindrical sidewall **22** extending therebetween. Sidewall **22** includes an inner surface **23** with an inside diameter "a" extending from top end **20** to a location substantially adjacent bottom end **18**.

[0057] Closure **14**, as shown in FIGS. 2-4, is unitarily molded from an elastomeric material and includes a top end **24** and a bottom end **26**. Portions of closure **14** adjacent top end **24** define a maximum outside diameter which exceeds the inside diameter "a" of tube **12**. Additionally, portions of closure **14** at top end **24** include a central recess **28** which defines a needle pierceable resealable septum. Portions of closure **14** extending upwardly from bottom end **26** taper from a minor diameter which is approximately equal to or slightly less than the inside diameter "a" of tube **12** to a major diameter that is greater than inside diameter "a". Thus, bottom end **26** of closure **14** can be urged into portions of tube **12** adjacent op n top nd **20** thereof, and the inh r nt resiliency of closure **14** will ensure a sealing ngagement with the inner circumferential surface of cylindrical sidewall **22** of tube **12**.

[0058] Closure **14** is formed to includ a bottom recess **30** xtending int bottom nd **26**. Bottom recess **30** is characterized by a central convex cone **32**. Additionally, a plurality f spaced apart r siliently d flectabl arcuate flanges **34** extend around the entrance to recess **30**. Flanges **34** function to releasably hold separator assembly **16**.

[0059] Separator assembly **16** includes a bellows **36**, a ballast **38** and a float **40**. Bellows **36**, as shown in FIGS. 5 and 6, is unitarily molded from a resiliently deformable material, that exhibits good sealing characteristics. More particularly, bellows **36** is symmetrical about a center axis and includes an upper end **42** a lower end **44**, and a hollow interior **45** that is open at lower end **44**. Portions of bellows **36** adjacent upper end **42** define an enlarged mounting head **46** with a top section that is convexly conical in an initial unbiased condition of bellows **36**. The conical section of bellows **36** adjacent upper end **42** can be deflected into a conical concave configuration that abuts conical portion **32** in recess **30** of closure **14**. Bellows **36** further includes a generally toroidal sealing section **47** intermediate upper and lower ends **42** and **44**. Toroidal sealing section **47** defines an outside diameter "b" which, in an unbiased condition of bellows **36**, slightly exceeds inside diameter "a" of tube **12**. However, oppositely directed forces on upper and lower ends **42** and **44** of bellows **36** will lengthen bellows **36** simultaneously reducing the diameter of toroidal sealing section **47** to a dimension less than "a". A narrow neck **48** is defined between mounting head **46** and toroidal sealing section **47**. Neck **48** is dimensioned to be engaged within the area defined by arcuate flanges **34** on closure **14**. Hollow interior **45** of bellows **36** includes an annular float mounting bead **49** at a location substantially aligned with neck **48**.

[0060] Portions of bellows **36** between toroidal sealing section **47** and lower end **44** define a generally cylindrical ballast mounting section **50** of outside diameter "c", inside diameter "d" and length "e". Ballast mounting section **50** terminates at an outwardly projecting flange **51** substantially adjacent lower end **44** of bellows **36**.

[0061] Ballast **38** of separator **16** is generally cylindrical tube unitarily formed from a material that will not react with blood or other liquid being separated and that has a density higher than the blood or other liquid being separated. Ballast **38** preferably is substantially tubular and includes opposed upper and lower ends **52** and **54**, as shown in FIGS. 7 and 8. Outer circumferential surface areas of ballast **38** define a maximum outside diameter "f" that is less than inside diameter "a" of tube **12**. Inner circumferential surface regions of ballast **38** are characterized by an inwardly directed flange **56** adjacent upper end **52**. Flange **56** defines an inside diameter "g" which is approximat ly equal to outsid diamet r "c" of ballast mounting section **50** of bellows **36**. Additionally, flange **56** of ballast **38** defines a length "h"

which is approximately qual t l ngth " " of ballast mounting section 50 on bellows 36. As a result, ballast 38 can b securely mounted to ballast mounting section 50 of bellows 36 at locations between flang 51 and toroidal sealing section 47. Portions of ballast 38 between flange 56 and lower end 54 of ballast 38 will project downwardly below lower end 44 of bellows 36 in this interengaged position.

[0062] Float 40 of separator 16 is a generally stepped tubular structure unitarily molded from a foam material having a density less than the density of the liquid phase of blood. Float 40 may be unitarily formed from a low density polyethylene. As shown in FIGS. 9-11, float 40 has an upper end 58, a lower end 60 and a passage 62 extending axially therebetween. Float 40 is formed with an annular groove 64 extending around the outer circumferential surface thereof at a location spaced slightly from upper end 58. Annular groove 64 is dimensioned to be resiliently engaged by inwardly directed annular bead 49 of bellows 36 for securely retaining portions of float 40 near upper end 58 to portions of bellows 36 near lower end 44 thereof. Additionally, groove 64 is configured to define apertures 65 that enable an air flow that insures narrowing of bellows 36 in the assembled condition of separator 16, as explained below.

[0063] Float 40 further includes narrow neck 66 at locations approximately midway between top and bottom ends 58 and 60. Neck 66 defines a diameter "I" which is less than inside diameter "d" of ballast mounting section 50 of bellows 36. As a result, neck 66 is freely movable in an axial direction within ballast mounting section 50 of bellows 36.

[0064] Float 40 further includes a substantially cylindrical base 68 defining a diameter "J" which is less than the inside diameter of ballast 38 between flange 56 and lower end 54. Thus, base 68 of float 40 can be slidably moved in an axial direction relative to portions of ballast 38 adjacent bottom end 54 thereof.

[0065] Separator 16 is assembled by resiliently engaging ballast mounting section 50 of bellows 36 with flange 56 of ballast 38. Float 40 then is urged upwardly through ballast 38 and into lower end 44 of bellows 36. After sufficient insertion, annular groove 64 of float 40 will engage annular bead 49 of bellows 36. Thus, bellows 36, ballast 38 and float 40 will be securely engaged with one another.

[0066] Portions of separator 16 adjacent upper end 42 of bellows 36 then are urged into recess 30 in bottom end 26 of closure 14. This insertion will cause arcuate flanges 34 of closure 14 to deflect. After sufficient insertion, arcuate flanges 34 will resiliently return toward an undeflected condition in which flanges 34 engage neck 48 of bellows 36. Additionally, the concave cone at upper end 42 of bellows 36 is deflected downwardly and into a convex shape by cone 32 of closure 14.

[0067] The subassembly comprised of closure 14 and s parator 16 then is ins rted into op n top 20 of tube 12 such that separator 16 and lower end 26 of closure 14 lie within tub 12, as shown in FIGS. 12 and 13. Closure 14 will sealingly engage against interior surface regions and top end 20 of tub 12. Additionally, toroidal section 48 of bellows 36 will s alingly engag against inner surface 23 f tube 12.

[0068] As shown in FIG. 13, a liquid sample is delivered to the tube by a needle that penetrates septum 28 of closure 14 and upper end 42 of bellows 36. For purposes of illustration only, the liquid sample is blood. Blood will flow through central opening 62 of float 40 and to bottom end 18 of tube 12. The needle then will be withdrawn from assembly 10. Upon removal of the needle septum 28 of closure 14 will reseal itself. Upper end 42 of bellows 36 also will reclose itself in a manner that will render it substantially impervious to fluid flow.

[0069] As shown in FIG. 14, when assembly 10 is subjected to centrifugation or to an axial centrifugation force, the respective phases of the blood will begin to separate so that the more dense phase comprising red blood cells will be displaced toward the bottom end 18 of tube 12 and so that the less dense phase comprising serum will be displaced to a location immediately above the denser phase and simultaneously, the centrifugal loads will urge ballast 38 toward bottom end 18 of tube 12 relative to float 40. This movement of ballast 38 will generate a longitudinal deformation of bellows 36. As a result, toroidal sealing section 48 will become longer and narrower and will be spaced concentrically inwardly from the inner surface 23 of sidewall 20 of tube 12. The smaller cross-section of toroidal section 48 will permit a movement of portions of bellows 36 adjacent lower end 44 to move toward bottom 18 of tube 12. Upper end 42 of bellows 36 initially will be retained adjacent closure 14 by arcuate flanges 34. However, all of closure 14 is resiliently deformable, and hence arcuate flanges 34 will resiliently deform downwardly in response to centrifugal loads created on separator 16, and particularly on ballast 38. Hence, separator 16 will separate from closure 14 and will begin moving in tube 12 toward bottom end 18, as shown in FIG. 14. Air in portions of tube 12 between the blood and separator 16 will flow around separator 16 and into sections of tube 12 between separator 16 and closure 14. After sufficient movement of separator 16, bottom end 54 of ballast 38 and/or bottom end 60 of float 40 will contact the top surface of the blood. This will leave trapped air within aperture 62 of float 40 that could impede further downward movement of separator 16. However, the defect in top 42 of bellows 36 caused by the needle cannula will enable trapped air to escape to regions of tube 12 between separator 16 and closure 14. Thus, ballast 38 will continue to urge separator 16 down into the separating blood. As noted above, separator 16 has an overall density between the densities of the formed and liquid phases of the blood. Consequently, separator 16 will stabilize in a position within tube 12 such that th formed phas of the blood will li between bottom nd 18 of tub 12 and separator 16, as shown in FIG. 15. The liquid phases of the blood will li

betw n s parator **16** and closure **14**.

[0070] After this stabilized state has been reached, th centrifuge will b stopped. Th t rmination of th centrifugal load will cause toroidal sealing section **48** f b llows **36** to resiliently r turn t ward its unbiased condition and into sealing engagement with interior surface **23** of tube **12**. Thus, the formed and liquid phases of blood will be separated efficiently and can be accessed separately for analysis.

[0071] An alternate embodiment of the tube assembly in accordance with the subject invention is identified generally by the numeral **110** in FIG. 16. Assembly **110** includes a tube **112**, a closure **114** and a separator **116**.

[0072] Tube **112** includes an open top **118**, a bottom **120** and a cylindrical wall **122** extending therebetween. Bottom **120** of tube **112** has an opening **124** extending therethrough. A bottom closure **126** is sealingly engaged in opening **124**. Bottom closure **126** is formed from a needle pierceable elastomer and enables the formed phase of a blood sample to be accessed directly from bottom **120** of tube **112**.

[0073] An alternate embodiment of the tube assembly of the present invention includes tube **112**, closure **114** and separator **116** wherein separator **116** is not mated with closure **114**.

[0074] Closure **114** includes an elastomeric stopper **128** sealingly engaged in open top **118** of tube **112**. Stopper **128** is provided with a centrally disposed needle pierceable septum **130**. Stopper **128** further includes a bottom recess **132** having a plurality of inwardly directed resiliently deflectable arcuate flanges **134** extending thereabout. Recess **132** is not provided with a concave cone.

[0075] Closure **114** further includes an outer cap **136** having an annular top wall **138** and a generally cylindrical skirt **140** depending downwardly from top wall **138**. Cap **136** is securely mounted around stopper **128** and is removably mountable over open top **118** of tube **112**. Top wall **138** of stopper **136** is provided with a central opening **142** that substantially registers with septum **130**.

[0076] Separator **116** includes a bellows **144**, a ballast **146** and a float **148**. Bellows **144** includes an upper end **150**, a lower end **152** and a toroidal sealing **154** therebetween. Unlike the prior embodiment, portions of bellows **144** adjacent upper end **150** are not conically generated. Rather, these upper portions of bellows **144** are substantially spherically generated and will nest with recess **132** in stopper **128** without the inward deformation that had been described with respect to the first embodiment. Portions of bellows **144** adjacent lower end **152** and adjacent toroidal sealing **154** are substantially the same as in the prior embodiment.

[0077] Ballast **146** includes an upper end **156** and a lower end **158**. Portions of ballast **146** in proximity to low r nd **158** defer from th prior embodiment in that inwardly directed flanges **160** ar provided for trapping float **148**. Thus, any post-assembly downward movem nt of float **148** relativ to ballast **146** is substantially prevented. Howev r, upward movement of float **148** relative to ballast **146** is possibl , and will occur during centrifugation.

Claims

1. An assembly for enabling separation of a fluid sample into a formed phase with a relatively high density and a liquid phase with a relatively low density, said assembly comprising:

   a tube having a closed bottom, an open top and a cylindrical sidewall extending therebetween;

   a closure sealingly engaged with said open top of said tube; and

   a separator comprising a deformable bellows having an upper end and a lower end, portions of said bellows between said upper and lower ends having an unbiased shape for sealing engagement with said cylindrical sidewall of said tube, a ballast securely mounted in proximity to said lower end of said bellows, said ballast being dimensioned to be spaced inwardly from said cylindrical sidewall of said tube and having a density greater than said density of said liquid phase of said fluid sample, and a float engageable with portions of said bellows in proximity to said upper end of said bellows, said float having a density less than said density of said formed phase of said fluid sample and less than said density of said formed phase of said fluid sample, whereby centrifugal forces applied to said assembly enable elongation of said bellows and movement of said separator in said tube to a location between said formed and liquid phases of said fluid sample.

2. The assembly of Claim 1, wherein the separator is substantially hollow.

3. The assembly of Claim 1, wherein said bellows includes a toroidal sealing section intermediate said upper and lower ends thereof, said toroidal sealing section, in an unbiased condition of said bellows, being engageable with said cylindrical sidewall of said tube.

4. The assembly of Claim 3, wherein said ballast is substantially tubular and is securely engaged around portions of bellows adjacent the lower end of said bellows.

5. Th assembly of Claim 3, wh r in said ballast is substantially tubular and is securely engaged

around portions of bellows adjacent th lower nd of said bellows.

6. The assembly of Claim 5, wherein said bellows is substantially hollow and has an inwardly direct d annular bead in proximity to said upper end of said bellows, said float having an annular groove engageable with said annular bead of said bellows, whereby buoyancy of said float urges said float toward said top of said tube for elongating said toroidal sealing section of said bellows.

7. The assembly of Claim 1, wherein said separator is releasably engaged with said closure, said separator being disengageable from said closure in response to centrifugal loads on said assembly.

8. The assembly of Claim 7, wherein the closure includes a centrally disposed needle pierceable septum for enabling placement of fluid in said tube.

9. The assembly of Claim 1, wherein said closure includes a lower end engageable in said open top of said tube, said lower end of said closure including a recess extending upwardly therein, a plurality of resiliently deflectable arc sections formed around said recess at said lower end of said closure, said bellows including a closure mounting section adjacent said upper end of said bellows, said closure mounting section having an inwardly extending groove engageable with resiliently deflectable arcs of said closure for releasably holding said bellows of said separator with said closure.

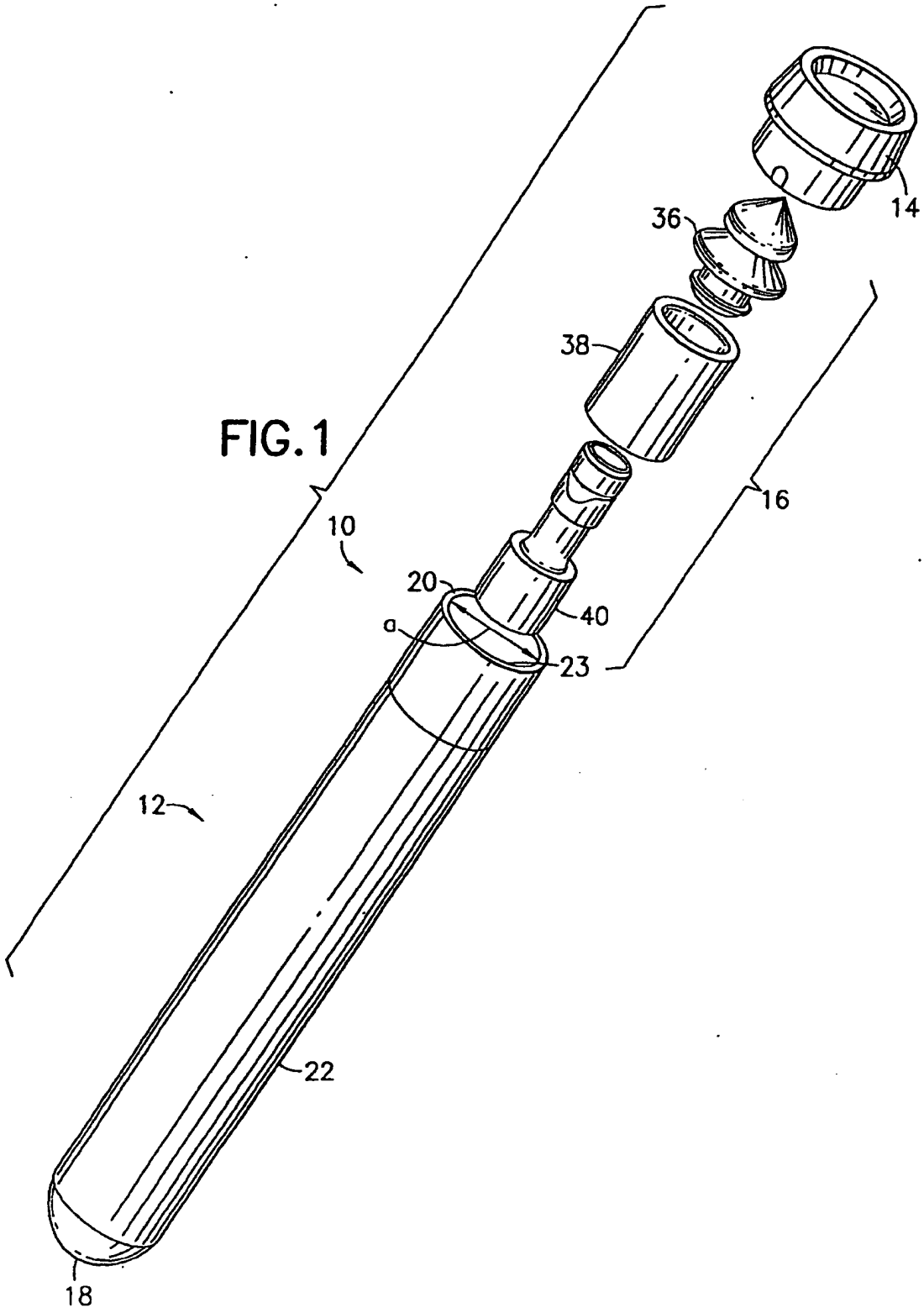
10. A separator for use with a blood collection tube to enable separation of blood into a formed phase with a relatively high density and a liquid phase with a relatively low density, said separator assembly comprising:

a deformable bellows having an upper end and a lower end, portions of said bellows between said upper and lower ends having an unbiased shape for sealing engagement within said tube;

a ballast securely mounted to said bellows in proximity to said lower end of said bellows, said ballast having cross-sectional dimensions smaller than said tube for free movement of said ballast in said tube, said ballast having a density greater than said density of said liquid phase of said blood; and

a float engageable with portions of said bellows in proximity to said upper end of said bellows, said float having a d nsity less than said d nsity of said liquid phas of said blood and less than said density of said form d phase of said blood, whereby centrifugal forces applied to said assembly enable longation of said bellows and movem nt f said separator ass mbly in said tub to a location between said formed and liquid phases of said blood.

FIG. 1



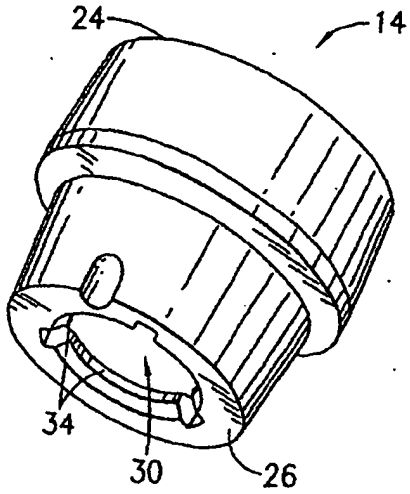


FIG.2

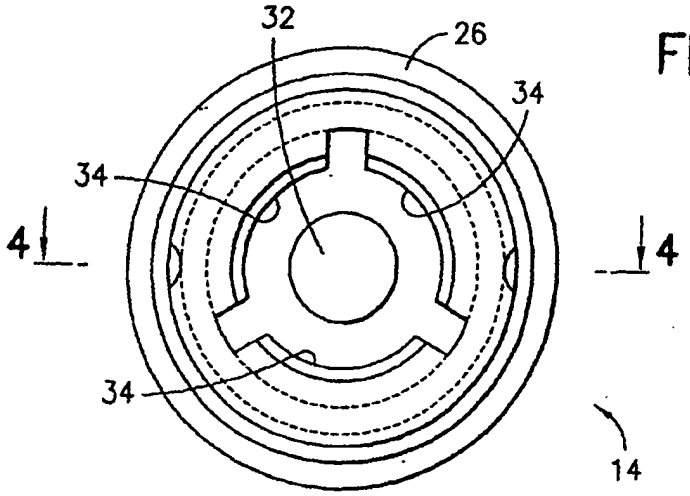


FIG.3

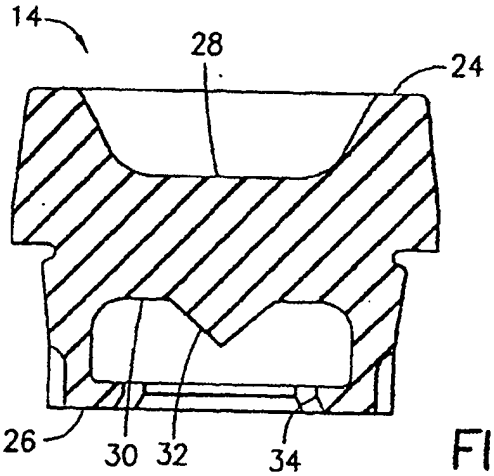


FIG.4

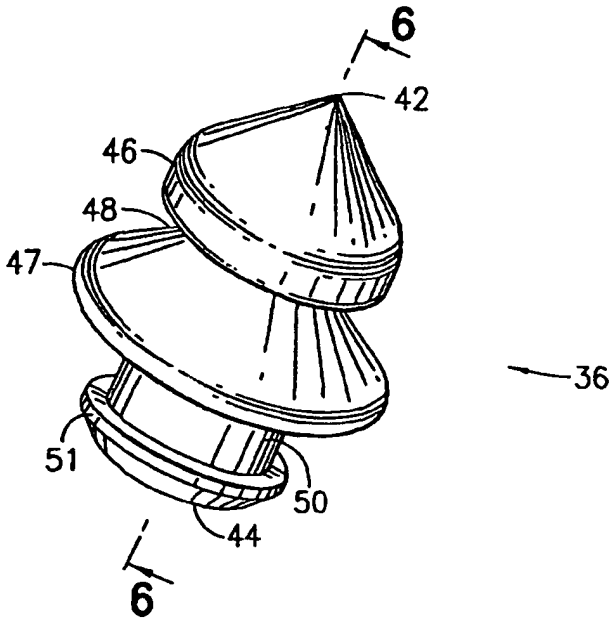


FIG.5

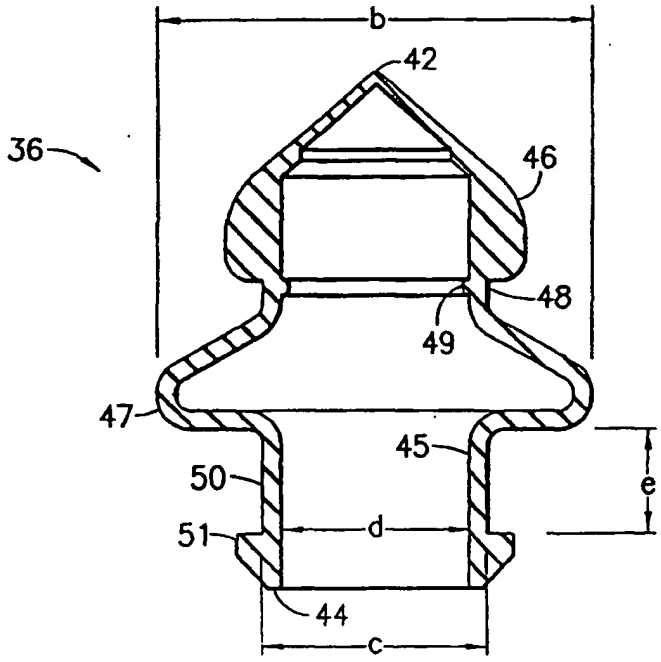


FIG.6

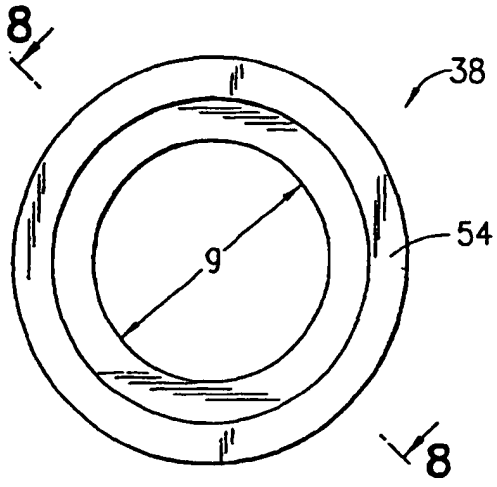


FIG.7

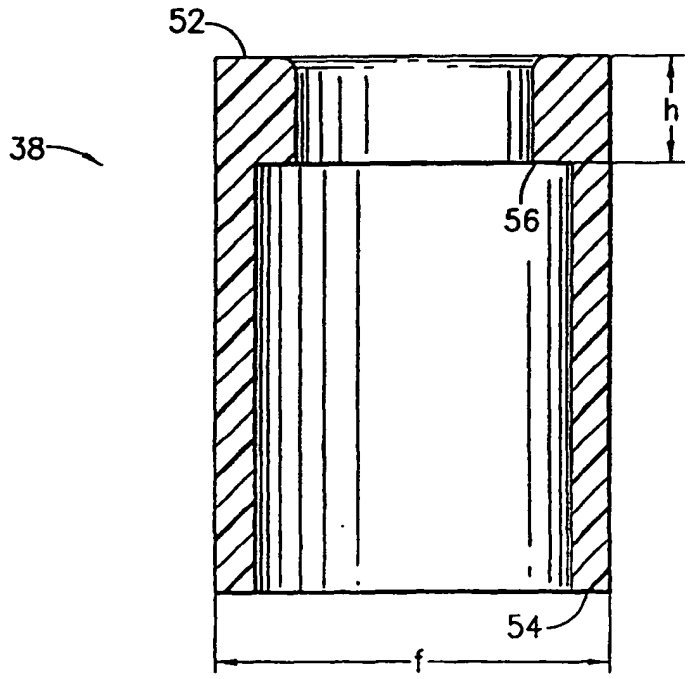


FIG.8

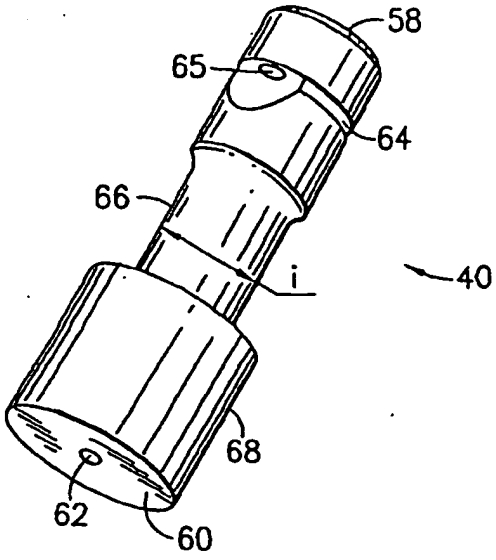


FIG.9

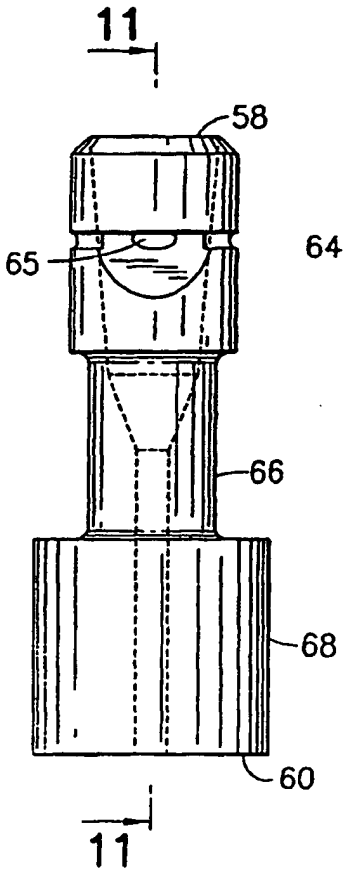


FIG.10

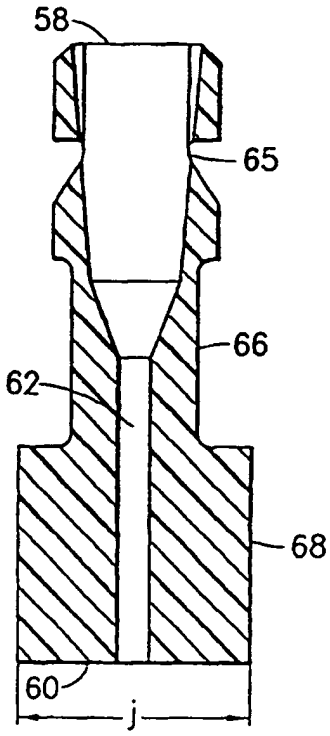


FIG.11

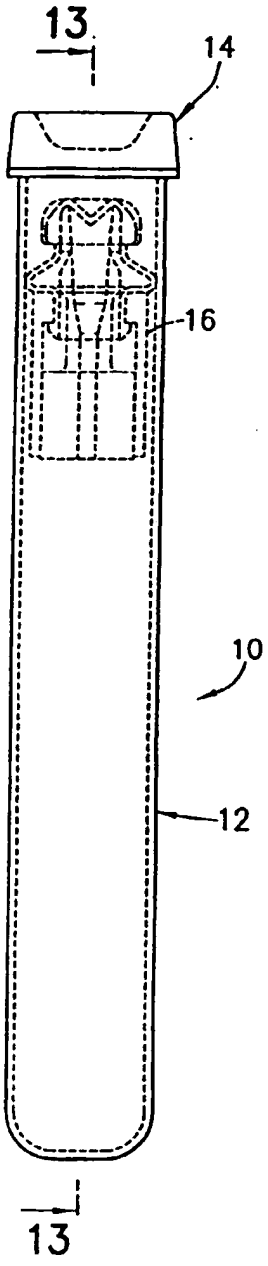


FIG.12

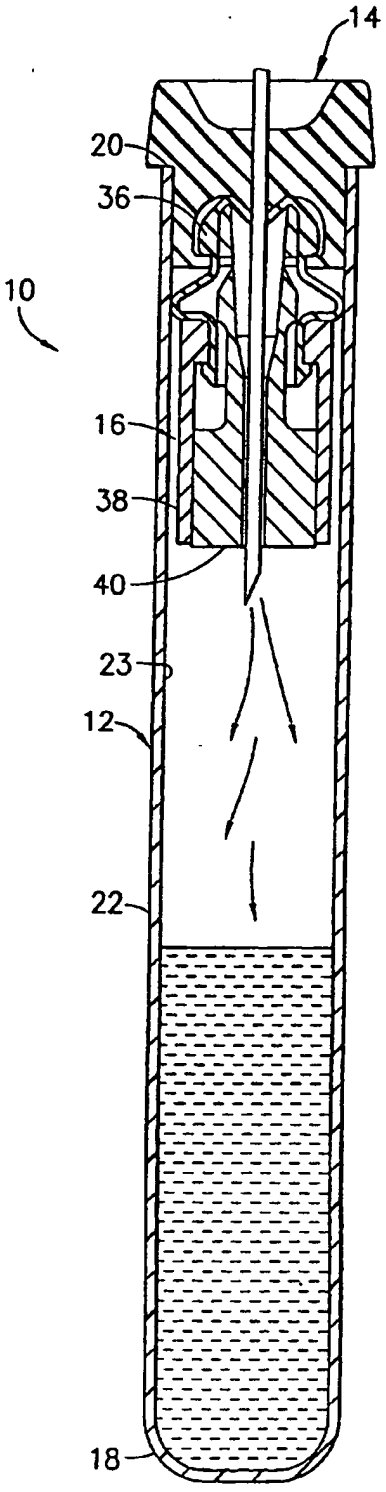


FIG.13

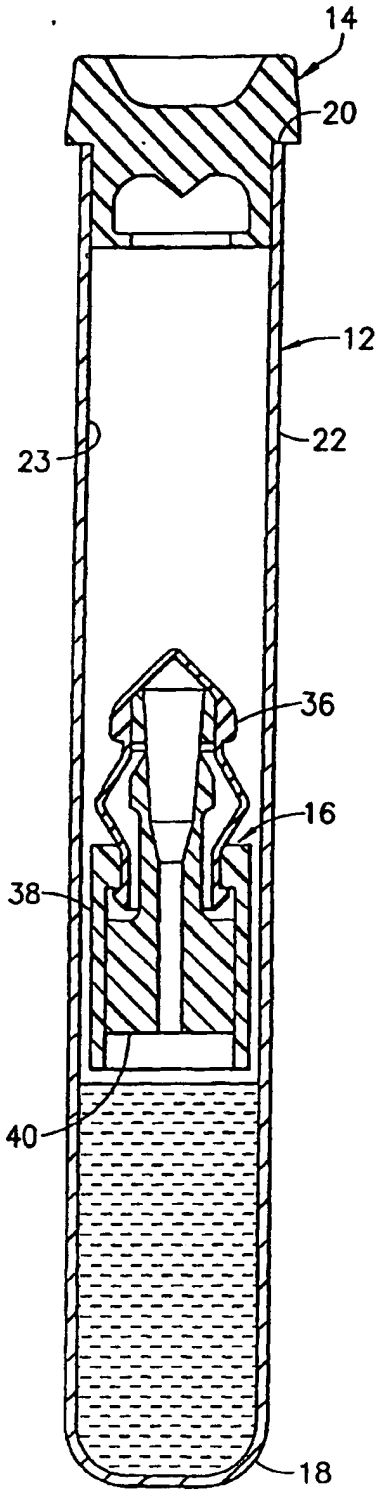


FIG.14

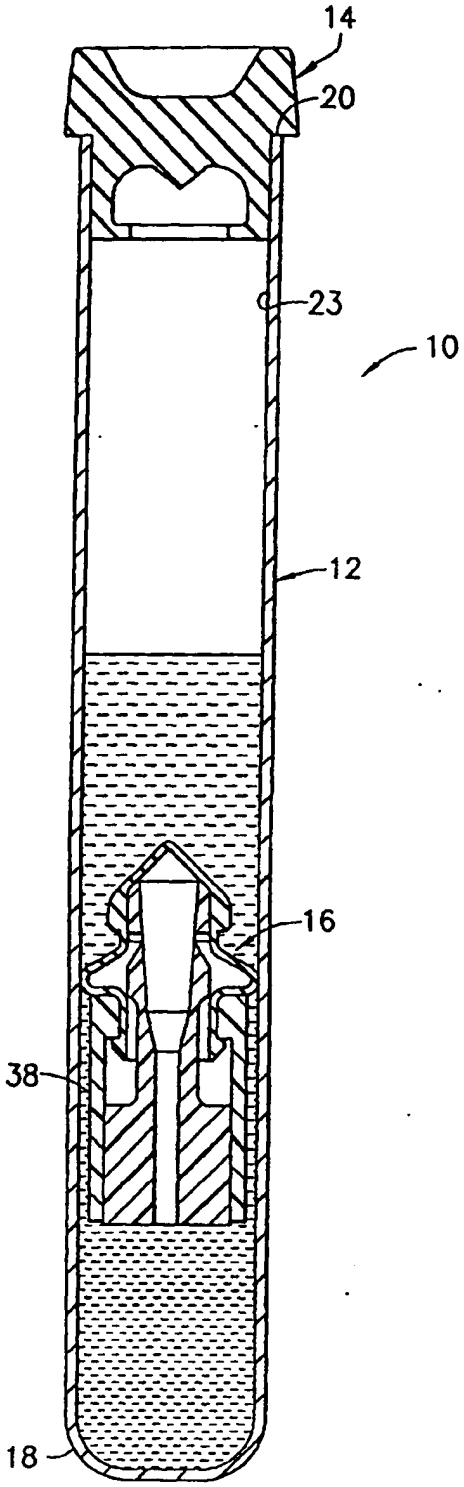


FIG.15

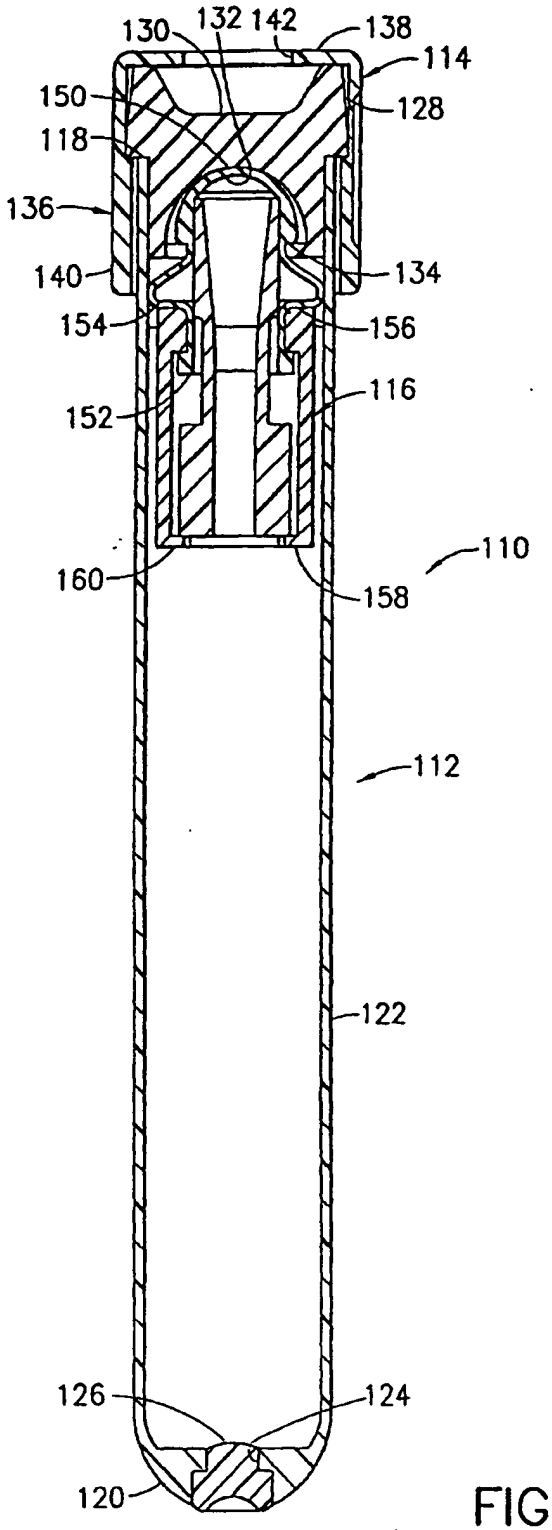

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FIG.16